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FLASHBLINDNESS FOLLOWING DOUBLE FLASH EXPOSURES

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Times required to detect a simple display were measured following exposure to adapting flashes separated by varying intervals ranging from 2 to 90 seconds. The results indicate that for flash durations of 165 microseconds, the approximate exposure duration wherein protection equipment is used, there are no consistent variations in response times as a function of interflash interval.

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INTRODUCTION

Flashblindness protection devices are being designed to provide protection from excessive exposure to unanticapated intense flashes of light. All of the devices require some sensing and reaction time with the result that a brief visual exposure to a sudden intense light source will occur. Personnel wearing these devices in an environment in which several sources of intense light flashes are present, may experience repeated flash exposures, which though not individually excessive, in combination, may be excessive.

If a protection device is worn in a repeated exposure environment, the duration of each exposure will be the same since the duration will be determined by the dynamic characteristics of the protection device. The interval between the exposures will vary. It is of interest from both a visual effect and a protection device design point of view to explore the effect of intervals between exposures on the adaptation produced by the exposures.

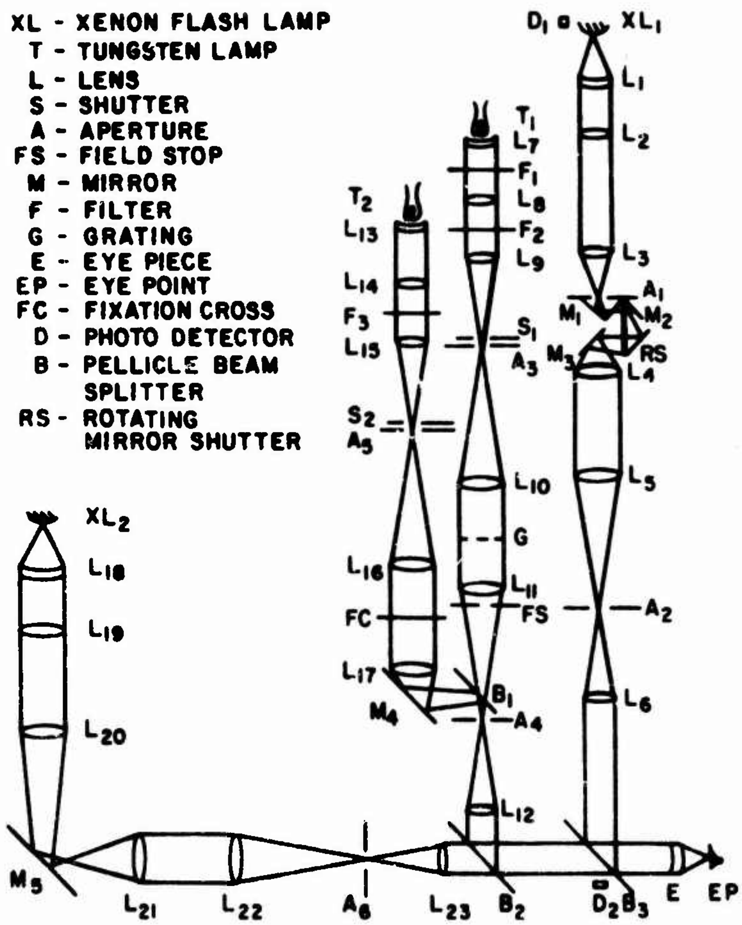
Earlier studies of the effects of multiple flash exposures have examined the effects of flashes separated by intervals ranging from 0 to 1 millisecond, reference (a), 3 minutes, reference (b), and 15, 45, 120 and 300 seconds, reference (c). The interflash intervals which are of particular interest to military planners are those ranging from approximately 2 seconds, the minimum exposure repetition interval which would occur for a wearer of currently proposed protection devices, to many seconds.

The present experiment was designed to explore the adapting effects of repeated flash exposures separated by intervals of from 2 to 90 seconds.

MATERIALS AND METHODS

APPARATUS

A diagram of the apparatus is shown in figure 1. The first adapting flash of a pair is provided by XL_1. After passing through the optical components L_1, L_2 and L_3, the beam is directed by the mirrors, M_1 and M_2, through the rotating mirror shutter, RS, which adjusts the duration of the first flash to match that of the second flash of the pair. The beam is then directed by M_3 through the optical components L_4, L_5 and L_6 into the pellicle beam splitter, B_3 which directs the beam into the ocular of the system, E, mounted in the wall of a light tight enclosure. To the eye of an observer, O, positioned at EP by a dental impression bite plate, the last lens of the ocular is seen in Maxwellian view and appears as a 60-degree visual field when no field stop is placed between L_4 and L_5. The second adapting flash of a pair is provided by XL_2 which is conducted to the ocular by the optical train from L_{18} through L_{23} and the pellicle beam splitters B_2 and B_3. The duration of the flash XL_2, as seen by O, is determined by the flash lamp electronics.



Optical System Diagram

FIGURE 1 - Schematic Diagram of Apparatus

The gaze of the observer is directed by a small red fixation cross, FC, (a clear cross on an opaque screen) transilluminated by light from the tungsten filament lamp, T_2. The intensity and chromatic composition of the light is controlled by neutral density and interference filters, F_3 located in a collimated portion of the beam. The beam which originates at T_2 is directed to the ocular through the optical components from L_{13} through L_{17}, the mirror M_4, and pellicle beam splitters B_1 and B_2. Control of the presentation of the beam is provided by the shutter, S_2.

The visual display, or target, is produced by a grating, G, of parallel opaque lines separated by clear spaces equal to the lines. The grating is mounted so that it can be oriented either horizontally or vertically in the view of the observer. The display illumination is provided by the tungsten lamp, T_1, and controlled in intensity by neutral density filters at F_1 and F_2. The beam which originates at T_1 is directed to the ocular through the optical components from L_7 through L_{12} and the pellicle beam splitter B_2. Control of the presentation of the beam is provided by a leaf camera shutter and paddle shutter located at S_1.

An observer positioned at EP sees one visual field composed of a fixation cross, a display grating and adapting flashes at the proper intervals and in the desired spatial relation. The stimulus sequencing, grating orientation, luminance adjustments, XL_1 flash duration and data recording are provided by a programmable digital logic system. The observer is provided with a foot switch which is used to initiate a trial sequence and two response buttons which provide an indication of target detection. A detailed description of the programmable portion of the apparatus is reported in reference (d).

CALIBRATION

The luminances of the adapting and display fields were calculated from the spectral irradiances measured with an EG&G, Inc. model 580/585 spectroradiometer. The maximum luminance of the display field was 3.6 log millilamberts. The luminance of the adapting field of XL_1 was 4.87 log Troland-seconds and the XL_2 was 4.74 log Troland-seconds. The duration of the flash provided by XL_2 was measured at one-third peak amplitude because of the exponential character of the light decay, and it was found to be 165 microseconds. The duration of the flash XL_1, which was controlled by the rotating mirror shutter and was therefore symmetrical, was measured at one-half peak amplitude and adjusted to a 165-microsecond duration. For the condition in which one flash was used, the XL_1 flash was adjusted to 330 microseconds. The duration and timing of the flashes were monitored by photo detectors at D_1 and D_2, the outputs of which were displayed on storage oscilloscopes.

Neutral density filters which were used to control luminances, and the interference filter which was used to control the fixation cross spectral quality were calibrated on a Perkin-Elmer spectrophotometer. The neutral density filters were cross calibrated with a MacBeth illuminometer. All calibrations were made of filters in the combinations used to provide the field luminances required. Densities of the display filters and display luminances are shown in table I.

TABLE I

DISPLAY FILTER DENSITIES AND CORRESPONDING DISPLAY LUMINANCES

Filter Density	Display Luminance (Log mL)
2.65	0.97
3.15	0.47
3.65	-0.03
4.15	-0.53
4.65	-1.03

PROCEDURE

The experimental design is shown in table II. In condition A, no adapting flash was used. In condition B, one 165-microsecond flash was used. In condition C, one 330-microsecond flash was used and in conditions D through J, two 165-microsecond flashes separated by 2, 5, 10, 15, 30, 60 and 90 seconds were used.

TABLE II

EXPERIMENTAL DESIGN

EXPERIMENTAL CONDITIONS

Flash		Flash Separation (Sec)							
Frequency	Duration (μsec)	0	2	5	10	15	30	60	90
No Flash		A							
1	165	B							
1	330	C							
2	165		D	E	F	G	H	I	J

Data were collected for one or two conditions during each experimental session. At the start of a session, the observer was seated in a light tight chamber and dark adapted for 30 minutes. At the end of the dark adaptation period, a buzzer sounded and the fixation cross was presented. The observer positioned himself with the aid of the bite board at the ocular and fixated the cross. When he was properly positioned and accommodated so that the cross was seen clearly, he pressed the foot switch to initiate a trial. The appropriate adapting condition occurred followed immediately by presentation of a display grating. As soon as the observer was able to determine the horizontal or vertical orientation of the grating and press the appropriate response switch, the shutter closed the display from the observer's view, the filters changed to adjust the display luminance, the grating orientation was adjusted according to a predetermined schedule, and the shutter opened to present the next display target to the observer. Following every fifth response, shutters closed both the display and fixation targets and a 5-minute readapting period was started. At the end of 5 minutes, the sequence started again. Six repetitions of each sequence were conducted for each adapting condition. Complete data were collected for three observers with and without pupil dilation.

TABLE III

MEDIAN RESPONSE TIMES FOR ALL OBSERVERS IN EACH EXPERIMENTAL CONDITION - PUPIL UNDILATED

Experimental Condition	Display Luminance (Log mL) 0.97	0.47	-0.03	-0.53	-1.03
A	0.23	1.37	2.60	5.14	19.61
B	1.25	2.35	3.63	7.33	34.96
C	2.18	3.47	5.07	10.45	36.70
D	1.55	2.79	4.09	9.16	38.35
E	1.50	3.67	4.29	10.49	39.05
F	1.27	2.50	3.83	7.12	33.14
G	1.24	2.47	3.80	6.12	29.16
H	1.45	2.80	4.08	7.17	46.72
I	1.49	2.84	4.27	8.43	97.23
J	1.45	2.66	4.12	7.43	26.10

TABLE IV

MEDIAN RESPONSE TIMES FOR ALL OBSERVERS IN EACH EXPERIMENTAL CONDITION - PUPIL DILATED

Experimental Condition	Display Luminance (Log mL) 0.97	0.47	-0.03	-0.53	-1.03
A	0.30	1.46	2.65	4.64	24.22
B	1.58	2.84	4.52	10.59	56.80
C	1.94	3.40	5.34	11.40	44.29
D	1.28	2.51	3.88	7.67	39.04
E	1.74	2.54	5.15	7.20	37.91
F	1.16	2.41	3.77	6.48	32.51
G	1.25	2.49	3.88	7.56	31.69
H	1.36	2.55	3.91	7.21	31.48
I	1.36	2.68	3.97	7.07	45.84
J	1.39	2.58	3.90	7.26	35.08

RESULTS

The median response times for all observers in each experimental condition are shown in tables II and IV. The response timer was triggered by the same pulse which triggered the target shutter, thus the times are measured from the foot switch activation in condition A, from the trailing edge of the single flashes in conditions B and C and from thetrailing edge of the second flash in conditions D through J.

The median response times for all observers in each experimental condition are shown graphically in figure 2. The results of an analysis of variance performed on the data are shown in table V. This analysis shows that pupil dilation did not affect the response time, either directly or in combination with any of the other factors. As would be expected, target luminance very strongly influenced the response time, and adapting condition significantly affected response time. To further assess the effect of adapting condition on response time, t, ratios for individual pairs of means were computed. Table VI shows the pairs of conditions for which the differences between means were significant.

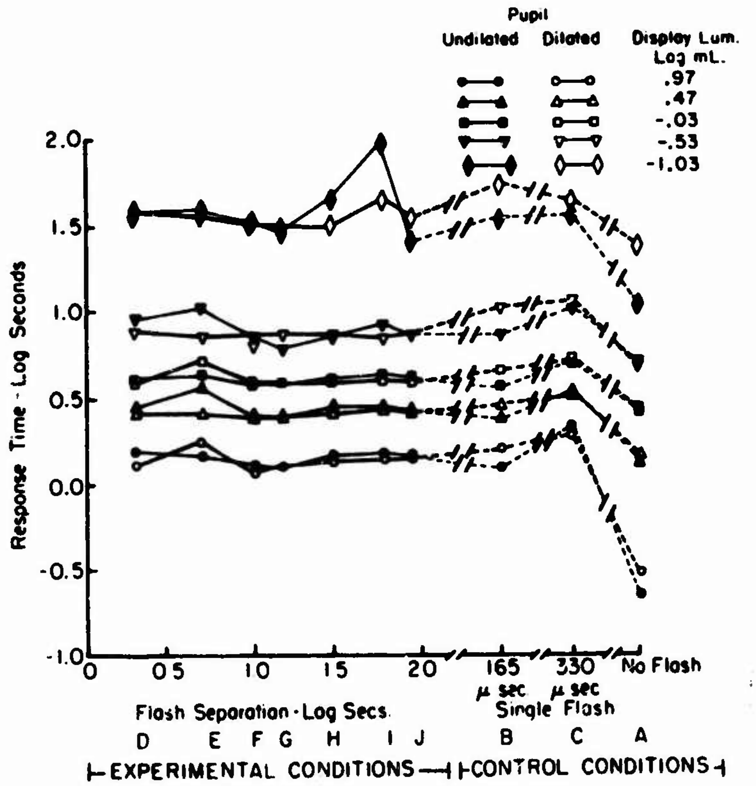


FIGURE 2 - Median Response Times for All Observers in Each Experimental Condition

TABLE V

ANALYSIS OF VARIANCE SUMMARY TABLE

Source of Variance	df	F
Target Luminance (T)	4	210.79*
Adapting Condition (C)	9	3.73*
Pupil Dilation (D)	1	.24
T x C	36	2.83*
T x D	4	.20
C x D	9	1.83
T x C x D	36	1.58
Error	200	

* P < 0.01

TABLE VI

SIGNIFICANT MEAN DIFFERENCES

Paired Experimental Conditions	Display Luminance (Log mL) 0.97	0.47	-0.03	-0.53	-1.03
I vs B				1.21	25.65
I vs C	0.63	0.67	1.00	3.17	31.04
I vs D				0.67	32.84
I vs E			0.51*	1.10	33.06
I vs F				0.95	38.71
I vs G				0.91	41.08
I vs H				0.56*	32.44
I vs J					40.94

For mean differences marked (*), $P < 0.05$; for all other differences, $P < 0.01$. (The no flash control condition (A) response times were significantly shorter than all other conditions and were not included in the table for simplicity purposes.)

DISCUSSION

The time required to detect a target following exposure to one or more flashes is significantly longer than the time required to detect that same target without prior flash exposure. Earlier experiments have shown that variations in duration of the flashes to which the eyes are exposed are associated with variations in time to detect a target. The experiment reported here shows that for a fixed flash duration, as would be the case for an aircrewman wearing dynamic flashblindness protection equipment, exposure to two flashes is not associated with simple variations in response time. In the present experiment, only the 60-second interflash interval produced consistently different response times for the two dimmest targets used. In some cases, a 60-second flash interval was associated with longer response times and in other cases, shorter response times.

The results obtained in the experiment reported here are not completely consistent with those obtained by earlier experiments, references (c) and (d). One significant difference in experimental conditions should be considered. In the experiment in which the interflash interval ranged from 15 to 300 seconds (reference (c)), the flash duration was 2 milliseconds, which is longer than the duration of concern for currently proposed protection devices, and significantly longer than the flashes in the present experiment. In the other experiment (references (b)), the flash duration was 250 microseconds, which is closer to the flash duration of concern, but th interflash intervals were 1 millisecond and shorter. In the first experiment (reference (c)) the two or more

long flashes produced longer recovery times than the single flash and seemed to show a consistent trend as a function of flash interval for at least one of the targets used. For the other target,neither interflash interval nor number of flashes produced any significant or consistent differences. In the second experiment (reference (b)), the short interflash intervals produced a significant differences, but the implication of the differences are difficult to interpret except as a trend toward longer recovery times for longer interflash intervals.

In the present experiment, in which the 60-second interflash interval is associated with significantly different response times to the two dimmest targets, the differences are not consistently in the same direction. Interpreting the meaning of such a result for planning purposes is difficult. When the results of all these studies are considered, the implication seems to be that for interflash intervals different from 60-seconds, multiple flashes need not concern military planners if flashblindness protection devices with occlusion times of 165 microseconds or less are worn by the affected personnel.

One other similarity between present data and earlier data warrants attention. Earlier experiments have shown that the temporal characteristics of a single flash have very little influence on flashblindness recovery time, and that the most significant and consistent feature of a flash in producing an adapting effect is the total integrated luminance of the flash, (reference (d)). The temporal significance of the adapting condition appears to extend to the present consideration. It seems reasonable to interpret the present data as implying that the total integrated luminance of a single flash is the most significant factor to consider, and that the temporal characteristics of multiple flash presentations are of little significance where eye protection is used.

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